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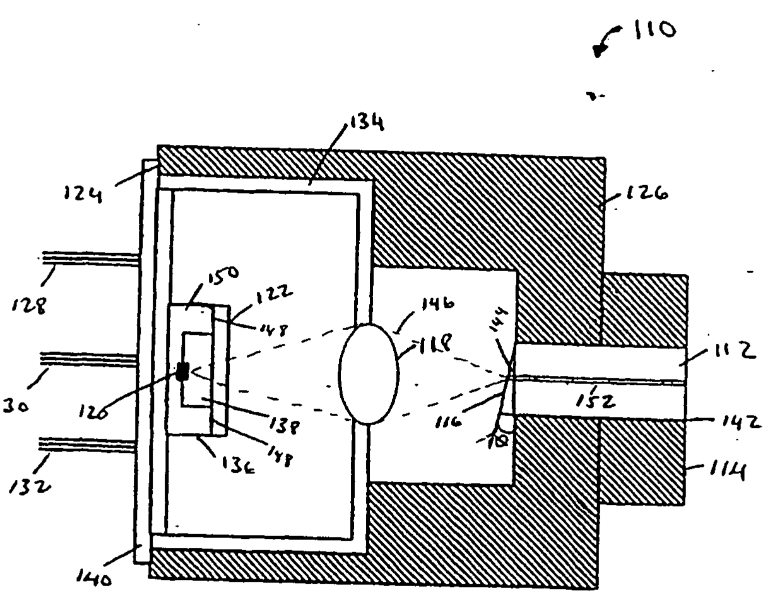
(54) Title: INTEGRATED WAVELENGTH SELECTIVE PHOTODIODE MODULE



(57) Abstract: An apparatus for providing optical wavelength selectivity that includes a housing; an optical transmitter in connection with the housing that delivers a beam of light; a light focusing arrangement located inside said housing and in alignment with the optical transmitter; an optical detector that receives the beam of light from the focusing arrangement; and a filter that allows a predetermined range of optical wavelengths to pass through to the optical detector. The apparatus combines multiple optical components into a single discrete TO-package for use in a high speed (Gigabit) optical communications network.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTEGRATED WAVELENGTH SELECTIVE PHOTODIODE MODULE

Field of the Invention

Embodiments of the present invention are directed to a method and apparatus for providing wavelength selectivity in a high speed optical communications network. More specifically, embodiments of the present invention are directed to an integrated wavelength selective photodiode module that combines multiple optical components into a single discrete package.

Background of the Invention

With the ever-increasing use of broadband communications in high speed optoelectronic networks, delivering a plurality of services to customers in a time-efficient and cost-effective manner is required. Typically, the plurality of services are delivered on a single information pipeline. The plurality of services may include cable television services, pay per view data channels, access to a global communications network, and telephone services. In general, providing the plurality of services to an end user on a single pipeline requires that the pipeline have a tremendous amount of bandwidth. Therefore, instead of delivering the plurality of services electrically, high bandwidth optical fiber communication networks are often used to deliver the plurality of services.

For long distance optical communications, erbium-doped fiber amplifiers (EDFAs) are often used. EDFAs are optical fibers doped with the rare earth element erbium (er^{-3}) which can amplify light in the 1550 nanometer region when pumped by an external source. Erbium-doped fibers are a critical component in various applications requiring optical amplification near the 1550 nanometer wavelength region. This includes booster amplifiers for long-haul regenerated systems, power amplifiers for terrestrial and cable TV applications, and small-signal amplifiers in optical receivers. In general, EDFAs are used to boost optical signals thereby eliminating the need for efficient conversion of optical signals to electrical signals. EDFAs are particularly useful for long-haul communication, and access applications like video-to-home, virtual local area network services, and voice over the Internet.

A well-known method for delivering a plurality of services along an optical fiber is referred to as wavelength division multiplexing (WDM). EDFAs have become an enabler for WDM systems and networks, and the use of WDM systems and networks has dramatically increased the capacity of optical fiber systems. Typically, in a WDM network, each service is

assigned a particular wavelength or channel. For example, services S1, S2, S3, ..., Sn are each assigned a particular frequency $\lambda_1, \lambda_2, \lambda_3, \ldots, \lambda_n$ and transmitted jointly along a single optical fiber transmission line. To prevent crosstalk or signal aliasing in the transmission line, the channels are generally separated by a frequency greater than or equal to about 200GHz. This is equivalent to a 1.6 nanometer channel separation. At a receiver end, the different services are differentiated by demultiplexing the wavelengths utilizing a combination of beam splitters, photodetectors and various bulky optical components.

The combination of broad gain bandwidth and small non-linearity has enabled multi-wavelength amplification by fiber amplifiers, reducing the need for complex and costly optoelectronic detection and retransmission. However, the spectral bandwidth of the conventional EDFA is limited. To cope with a demand for greater transmission capacity, new optical bands have been developed using long wavelength band EDFAs (L-band-EDFAs), erbium doped fluoride fiber amplifiers (EDFFAs), thulium doped fiber amplifiers (TDFAs), praseodymium-doped fluoride fiber amplifiers (PDFFAs) and Raman amplifiers.

In addition, broadband operators have introduced a method of transmitting even more data on an optical fiber transmission line. The method is called dense wavelength division multiplexing (DWDM). By utilizing DWDM, even more wavelengths are compressed onto an optical fiber. In a DWDM system, the wavelengths are generally separated by 50GHz or 0.4 nanometers. Therefore, in a DWDM system the channel separation is less than that for WDM thereby providing a capability of delivering even more services to an end user on a single fiber. By using DWDM, up to 80, and theoretically more, separate channels of data can be multiplexed utilizing a beam of light transmitted along an optical fiber.

The number of channels provided in a DWDM system may be further improved by using Raman amplifiers. In general, a Raman amplification system includes a continuous wave laser signal. The laser signal is generally launched from a receiver end of an optical fiber and is referred to as a backward signal. The backward signal is used to pump the optical fiber. As the backward signal interacts with a forward travelling wave of a different wavelength, signal amplification is achieved. In general, amplification is caused by a nonlinear interaction that takes place at high powers. Because amplification is generally achieved when the signals overlap, the interaction results in the full transmission length of the fiber being turned into an amplifier. Typically, the overall width of the band is determined by the gain or amplification spectrum. Thus, a larger gain translates into a greater bandwidth or an ability to provide more

channels. Typically, a practical limitation to bandwidth capacity is determined by the linewidth of the lasers being used.

Although spectral bandwidths have improved, a high speed, compact and efficient means for separating light wavelengths at a receiver end of an optical communications network is not yet available. The prior art discloses wavelength discriminators or mechanisms for demultiplexing wavelengths at a receiver end. However, the wavelength discriminators of the prior art typically comprise combinations of bulky fiber gratings, prisms or filters to separate the closely packed wavelengths. A low cost, discrete, compact solution is required for both separating the closely packed wavelengths being transmitted at gigabit rates through an optical fiber communications network, and for separating pump wavelengths associated with boosting optical signals in erbium doped fibers and Raman amplifiers.

Summary of the Invention

Embodiments of the present invention relate to an integrated wavelength selective photodiode module that combines multiple optical components into a single discrete package for use in a high speed optical communications network. The present invention provides a low cost, discrete, compact solution for both separating closely packed wavelengths being transmitted at gigabit rates through an optical fiber communications network, and for separating pump wavelengths often associated with boosting optical signals in erbium doped fibers and Raman amplifiers. In one embodiment of the invention, the integrated wavelength selective photodiode module includes a fiber for transmitting an incoming optical beam, a lens combination for focusing the incoming optical beam, a filter for filtering undesirable wavelengths, and a photodiode for detecting predetermined wavelengths.

In general, in one aspect, an embodiment of the invention features an apparatus for providing optical wavelength selectivity. The apparatus includes a housing, an optical transmitter in connection with the housing that delivers a beam of light, a light focusing arrangement located inside said housing and in alignment with the optical transmitter, an optical detector that receives the beam of light from the focusing arrangement, and a filter that allows a predetermined range of optical wavelengths to pass through to the optical detector.

In another embodiment of the invention, the optical detector may include an array of optical detectors wherein each optical detector operates at greater than or equal to approximately one Gigabit per second. In addition, the array of optical detectors is made up of a plurality of independent optical detectors. As a result, when the array of optical detectors is placed in

combination with a diffraction grating, each of the plurality of independent detectors may be used to detect a specific wavelength. Accordingly, a wavelength $\lambda_1, \lambda_2, \ldots, \lambda_n$ would only be detected by a corresponding detector $D_1, D_2, \ldots, D_n$. As a result, high speed independent channel tracking may be provided.

In another aspect of the invention, the optical detector includes a PIN photodiode made of a quaternary semiconducting material such as Indium-Gallium-Arsenide-Phosphide. In addition, the PIN photodiode operates at a speed of approximately one Gigabit per second.

In one embodiment of the invention, the optical transmitter includes an erbium doped fiber amplifier. In yet another aspect of the invention, the optical transmitter includes a ribbon fiber having a plurality of fibers each transmitting a separate range of wavelengths.

In another embodiment of the invention, the filter may include either a diffraction grating, or a prism. Alternatively, the filter may include a grating in combination with an optical fiber.

In still another embodiment of the invention, the integrated wavelength selective photodiode module includes an apparatus for providing wavelength selectivity that utilizes a single miniaturized coaxial package that includes a housing that measures less than or equal to about twenty five millimeters; an optical transmission means that transmits a beam of light; a transducer that receives the beam of light; a light focusing arrangement that focuses the beam of light onto the transducer; and a filtering means that allows a predetermined range of optical wavelengths to pass through to the transducer.

In an alternative embodiment of the invention, the integrated wavelength selective photodiode module includes a method of providing wavelength selectivity for high speed optical transmissions. the steps of the method include receiving a beam of light; filtering the beam of light; focusing the beam of light onto a transducer; and utilizing a miniaturized discrete package that includes at least a filter for filtering the beam of light, and a high speed transducer that produces an electrical signal in response to the beam of light.

In yet another embodiment of the invention, the integrated wavelength selective photodiode module includes an optical receiver assembly that includes a housing, and mounted inside said housing, an optical fiber that provides a light source, a lens focusing arrangement, an optical detector and a filter that allows a predetermined range of optical wavelengths to pass through to the optical detector. In one aspect of the invention, a portion of the housing includes an index matching fluid.

In one embodiment of the invention, the integrated wavelength selective photodiode module may be used to filter pump frequency wavelengths utilized in conjunction with an

erbium doped fiber amplifier. In an alternative embodiment, the integrated wavelength selective photodiode module may be used in conjunction with a system that utilizes Raman amplification.

In still another embodiment, the present invention includes a method of manufacturing an optical spectrum analyzer. The steps of the method include providing a housing able to receive a beam of light; providing a transducer that receives the beam of light within said housing; providing a focusing arrangement that directs the beam of light onto the transducer; and providing means for blocking while allowing a predetermined range of optical wavelengths to pass through to the transducer.

The foregoing and other objects, aspects, features and advantages of the invention will become more apparent from the following description and from the claims.

Brief Description of the Drawings

In the drawings, like reference characters generally refer to the same parts throughout the different views. Also, the drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention.

FIG. 1 is a cross-sectional view of an integrated wavelength selective photodiode module in accordance with one embodiment of the present invention;

FIG. 2 is a schematic of an integrated wavelength selective photodiode module in accordance with one embodiment of the present invention utilizing a ribbon fiber;

FIG. 3 is a schematic of a side view of an integrated wavelength selective photodiode module in accordance with one embodiment of the present invention utilizing a TO-46 diode package configuration;

FIG. 4 is a schematic of an integrated wavelength selective photodiode module in accordance with one embodiment of the present invention utilizing a filter/grating combination; and

FIG. 5 is a schematic of an integrated wavelength selective photodiode module in accordance with one embodiment the present invention wherein a filter and a lens are incorporated on a surface of a TO-46 diode package.

Detailed Description

Embodiments of an integrated wavelength selective photodiode module in accordance with the present invention will now be described with reference to FIGS. 1-5. In contrast with prior art filtering modules for dense wavelength division multiplexing systems, embodiments of

the present invention reduce the number of separate fiber optic components required, and provide discrete systems for separating closely packed wavelengths being transmitted at gigabit rates through an optical fiber communications network.

Referring to FIG. 1, a cross-sectional view of an embodiment of an integrated wavelength selective photodiode module 110 is shown. The integrated wavelength selective photodiode module 110 includes a housing 114 in which several components are mounted: an optical fiber 112 for transmitting an incoming optical beam 146, the optical fiber 112 includes a central core 152 and an end face 116. The housing 114 further includes a lens 118 for focusing the incoming optical beam 146, a passband filter 122 for filtering predetermined wavelengths, and a photodiode 120 for detecting predetermined wavelengths.

As shown in FIG. 1, the housing 114 includes a bore 142 and a cap 126 having a metal bushing. The bore 142 passes through the cap 126. The cap 126 holds the optical fiber 112 in place. In one embodiment of the invention, the optical fiber 112 is an erbium doped fiber amplifier (EDFA). The optical fiber 112 includes a cleaved end face 116 having an optimized angle (ϕ) that reduces back reflection of the incoming signal within the housing 114. In one embodiment of the invention, the end face 116 of the fiber 112 has an angle approximately equal to about eight degrees. As shown in FIG. 1, the angle ϕ is measured relative to a flat end face 144 of the optical fiber 112. The central core 152 of the optical fiber 112 is perpendicular to the flat end face 144.

In order to further enhance light focusing capabilities, the lens 118 is utilized. The optical fiber 112 is aligned along an optical path defined by the central core region 152 of the optical fiber 112 with the lens 118 being located in that optical path. In one embodiment of the invention, the focusing lens 118 is placed at a distance of approximately one millimeter from the central core region 152 of the cleaved face 116 of the optical fiber 112, and at a distance of approximately one millimeter from the photodiode 120. In an alternative embodiment of the invention, the focusing lens 118 and the end face 116 of the optical fiber 112 may be replaced with a spherically tipped fiber, or with a fiber having a convex or a concave shaped end face for focusing a beam of light. In one embodiment, the shaped end face simulates various types of lenses or lens combinations.

The lens 118 focuses the optical beam 146 onto a photodiode 120. However, before the optical beam 146 reaches the photodiode 120, the optical beam is directed through a passband filter 122. In one embodiment of the invention, the passband filter 122 is used to remove optical wavelengths having a frequency typically referred to as a "pump frequency". Specifically, the

passband filter 122 is used to block pump frequencies having wavelengths that range from 1450nm to 1520nm, or from 970nm to 990nm, or both. However, optical signals with wavelengths ranging from 1530nm to 1560nm are allowed to pass through to the photodiode 120. When optical signals having the desired wavelengths are detected by the photodiode 120, a photocurrent is generated. The photocurrent may be collected by making contact to either a cathode 128 or an anode 132.

Alternatively, the integrated wavelength selective photodiode module 110 may also be used in a system that utilizes Raman amplification. Typically, a Raman amplification system includes a continuous wave laser signal. The laser signal is generally launched from a receiver end of an optical fiber and is referred to as a backward signal. The backwards signal (typically a 1240nm optical signal referred to as a Raman pump wavelength) is used to pump the optical fiber. As the backward signal interacts with a forward travelling wave of a different wavelength, signal amplification is achieved. In general, amplification is caused by a nonlinear interaction between a photon and a phonon, and gain is generally achieved when the signals overlap. The interaction results in the full transmission length of the fiber functioning as an amplifier. In one embodiment of the invention, a wavelength selective photodiode module 110 could be used to detect predetermined optical wavelengths while filtering any residual optical power at the Raman pump wavelengths.

In one embodiment of the invention, the photodiode 120 is a PIN indium-gallium-arsenide-phosphide (InGaAsP) photodiode seated at a base of a well 138 of a ceramic submount 136. The ceramic submount 136 is placed on a header 140 to which the cap 126 is also attached. The ceramic submount 136 has a u-shaped configuration. In one aspect of the invention, the ceramic submount 136 provides electrical connections and mechanical support for the photodiode 120 mounted at a base of the well 138. The u-shaped ceramic submount 136 also provides mechanical support for the passband filter 122. The passband filter 122 is mounted on two ridge like posts 150 of the u-shaped ceramic submount 136 and held in place by either a solder or an adhesive 148. In one embodiment of the invention, the passband filter 122 is a glass substrate that includes several layers of oxide. In one embodiment of the invention, the layers of oxide may include but are not limited to titanium oxide (TiO2) or silicon dioxide (SiO2). In one aspect of the invention, the layers of oxide number greater than 50 and have a total thickness between 10-50 micrometers wherein each layer is approximately one quarter wavelength thick. In an alternative embodiment of the invention, the passband filter 122 is mounted on an end face 116 of the optical fiber 112. In that embodiment, the passband filter 122 may be incorporated

onto the end face 116 of the fiber utilizing a deposition procedure, or by fusing the passband filter 122 to the fiber 112. In another embodiment of the invention, the passband filter 122 is created from a semiconducting material designed to absorb predetermined wavelengths.

In an alternate embodiment of the invention, the PIN photodiode 120 may be replaced by an array of photodiodes each optimized for detecting particular wavelengths. Alternatively, the PIN photodiode 120 may include an avalanche photodiode which provides substantial internal gain. An avalanche PIN photodiode that meets the required criteria has been described in an article entitled "Planar Bulk-InP Avalanche Photodiode Design For 2.5 and 10Gb/s Applications" by M. Itzler et al.; and in an article entitled "Manufacturable Planar Bulk-InP Avalanche Photodiodes For a 10 Gb/s Applications" by M. Itzler et al. Both articles are incorporated herein by reference. Further, an embodiment of the high speed photodiode 120 is commercially available in a packaged optical receiver module through EPITAXX, Inc of West Trenton, New Jersey a subsidiary of Nippon Sheet Glass Company, Limited of Tokyo, Japan.

In yet another embodiment of the invention, the passband filter 122 is mounted inside a hermetically sealed cap 134. In this embodiment, the integrated wavelength selective photodiode module 110 is hermetically sealed to provide a robust optical design that minimizes environmental effects such as humidity, and dust which over a period of time would decrease spectral responsivity and overall system efficiencies. As a result, the integrated wavelength selective photodiode module 110 utilizing the passband filter 122 provides a single discrete module for obtaining an improved spectral response and an electrical signal or photocurrent that relates only to a desired range of pass through frequencies. Furthermore, the overall size of the integrated wavelength selective photodiode module 110 is comparable in size to that of any off-the-shelf TO-46 diode package.

In another embodiment of the invention, the integrated wavelength selective photodiode module 110 may be incorporated in a dual-in-line (DIL) package utilizing flat surface-mountable components. In that embodiment, the fiber 112, the lens 118, the filter 122, and the photodiode 120 are mounted on a flat surface in a box-shaped housing so that the relative positions and orientations of the components are maintained as shown in FIG. 1.

In still another embodiment of the invention, the optical fiber 112 may be a ribbon fiber 212 having a plurality of separate fibers 212a, 212b, 212c, and 212d as shown in FIG. 2. Each fiber of the ribbon fiber 212 carries a different wavelength $\lambda_1, \lambda_2, \lambda_3, \ldots, \lambda_n$. Each of the fibers 212a - 212d are aligned with a corresponding photodiode 120a - 120d. Each of the photodiodes 120a - 120d is designed to detect a predetermined wavelength.

FIG. 3 is a schematic of a side view of an embodiment of the integrated wavelength selective photodiode module 110 incorporated within a TO-46 package configuration 510 with a fiber pigtail 516. As shown in FIG. 3, a base of the header 140 has a thickness that is approximately equal to about 4.2mm. In addition, a horizontal diameter of the metal bushing cap 126 is approximately equal to about 5.55mm. A length as measured from a base of the header 140 to a base of a cap 512 that holds a fiber sleeve 514 in place is approximately equal to about 19.05mm. A length from a base of the cap 512 to an edge of the fiber sleeve 514 is approximately equal to about 360mm. A length from the base of the cap 512 to an end of a fiber 112 is approximately equal to about 1.25 meters. In one embodiment of the invention, the fiber sleeve 514 holds a 250 micron diameter fiber in place and protects the fiber 112 from environmental effects while providing tensile strength to the fiber. Alternatively, the fiber 112 could have a 900 micron diameter and include a tight buffered construction in which case the fiber sleeve 514 is unnecessary.

In another embodiment of the invention, a diffraction grating 322 may be used to provide wavelength selectivity. FIG. 4 shows an embodiment 310 of the present invention utilizing a diffraction grating/filter combination. In one embodiment, the diffraction grating 322 includes a periodic feature that occurs on a top surface of the glass substrate. The diffraction grating may either be etched into the glass substrate, or deposited onto the glass substrate utilizing photolithography. The diffraction grating varies periodically along a particular direction. Based upon that periodicity, the grating scatters light either away from a grating surface or couples light through the grating. The periodicity of the diffraction grating 322 is generally represented by the equation

$$\Lambda = \frac{\lambda}{2nSin\alpha}$$

where n represents the index of refraction, and λ represents a diffracted wavelength, α represents the angle of reflection of the optical beam as measured from a line orthogonal to a surface of the diffraction grating, and Λ represents the grating periodicity. It is well known in the art, that a diffraction grating may be produced in a manner that diffracts a predetermined wavelength λ (or range of wavelengths) and allows other wavelengths to pass through undeviated. Accordingly, the grating could be used to diffract the pump frequencies while allowing optical signals having wavelengths from 1530nm to 1570nm (or some other range of desired wavelengths) to pass through to the photodiode 120.

Alternatively, the diffraction grating could be used to diffract predetermined wavelengths 146′ towards an array of optical detectors. The array of optical detectors are made up of a plurality of independent optical detectors 120. Each of the plurality of independent detectors 120 may be used to detect either a specific wavelength or range of wavelengths. As a result, wavelengths $\lambda_1, \lambda_2, \ldots, \lambda_n$ would only be detected by a corresponding detector $D_1, D_2, \ldots, D_n$. In one embodiment of the invention, each detector would be located at a predetermined angle from the grating associated with a particular wavelength. As a result, high speed independent channel tracking could be provided. In yet another embodiment of the invention, independent channel tracking could similarly be achieved by utilizing a prism. In a further embodiment of the invention, the filter/grating combination may be included on either a cleaved or polished endface of the optical fiber 112. In a further embodiment of the invention, the filter/grating combination could have spatially varying transmission properties such that only selected wavelengths are passed through a particular section of the filter to an array of photodiodes 120 located directly beneath the filter/grating.

In still another embodiment 410 of the invention, the passband filter 122 may be incorporated on the lens 118. In addition, the combination may be held in place utilizing a top surface 412 of the cap 126 as shown in FIG. 5. In that embodiment, a passband filter 122 and lens 118 combination are incorporated directly into a TO-46 package. The photodiode 120 is shown mounted on a stage 414 having electrical connections to an anode 128, a cathode 132 and a grounding lead 130.

In one aspect of the invention, the photodiode 120 is a high speed avalanche photodiode optimized to function at greater than or equal to approximately one Gigabit per second. Therefore, the integrated wavelength selective photodiode module 110 may be used to demultiplex closely packed wavelengths being transmitted in a high speed optical communications network that utilizes wavelength division multiplexing (WDM) or dense wave division multiplexing (DWDM).

As discussed, an integrated wavelength selective photodiode module 110, a fiber 112 for transmitting an incoming optical beam 146, a lens 118 for focusing the incoming optical beam 146, a passband filter 122 for filtering undesirable wavelengths, and a photodiode 120 for detecting predetermined wavelengths has been combined into a miniaturized discrete package. The overall size of the integrated wavelength selective photodiode module 110 is comparable to that of an off-the-shelf TO-46 diode package having a fiber pigtail. The system provides a robust optical design that minimizes environmental effects which over a period of time will provide a

stable spectral sensitivity and improved overall device efficiencies. Although the integrated wavelength selective photodiode module 110 has been described for use in a high speed optical network, the integrated wavelength selective photodiode module may be utilized in a continuos wave arrangement with operating speeds well below a Gigahertz.

Variations, modifications and other implementations of what is described herein will occur to those of ordinary skill in the art without departing from the spirit and the scope of the invention as claimed. Accordingly, the invention is to be defined not by the preceding illustrative description but instead by the spirit and scope of the following claims.

CLAIMS

1. An apparatus for providing optical wavelength selectivity, comprising:

a housing;

an optical transmitter in connection with the housing that delivers a beam of light;

a light focusing arrangement located inside said housing and in alignment with the optical transmitter;

an optical detector that receives the beam of light from the focusing arrangement; and

a filter that allows a predetermined range of optical wavelengths to pass through to the optical detector.

2. The apparatus of claim 1 wherein the optical detector includes a PIN photodiode.

3. The apparatus of claim 2 wherein the PIN photodiode comprises a quaternary semiconducting material.

4. The apparatus of claim 3 wherein the quaternary semiconducting material includes Indium-Gallium-Arsenide-Phosphide.

5. The apparatus of claim 2 wherein the PIN photodiode operates at a speed of approximately one Gigabit per second.

6. The apparatus of claim 1 wherein the optical transmitter includes an erbium doped optical fiber amplifier.

7. The apparatus of claim 1 wherein the optical transmitter includes a ribbon fiber.

8. The apparatus of claim 1 wherein a length of the housing is less than or equal to approximately twenty-five millimeters.

9. The apparatus of claim 1 wherein the housing is a compact coaxial package.

10. The apparatus of claim 1 wherein the filter includes a grating.

11. The apparatus of claim 1 wherein the filter includes a prism.

12. The apparatus of claim 1 wherein the filter comprises a grating in combination with the optical transmitter.

13. The apparatus of claim 1 wherein the optical detector includes an array of optical detectors.

14. An apparatus for providing wavelength selectivity utilizing a single miniaturized coaxial package, comprising:

a housing;

an optical transmission means that transmits a beam of light;

a transducer that receives the beam of light;

a light focusing arrangement that focuses the beam of light onto the transducer; and

means for blocking while allowing a predetermined range of optical wavelengths to pass through to the transducer.

15. The apparatus of claim 14 wherein the transducer includes a PIN photodiode that operates at a speed of approximately one Gigabit per second.

16. A method of providing wavelength selectivity for high speed optical transmissions, the steps of the method comprising:

receiving a beam of light utilizing a discrete package having a filter for filtering the beam of light;

focusing the beam of light onto a transducer; and

producing an electrical signal in response to the beam of light.

17. The method of claim 16 wherein the transducer includes a PIN photodiode that operates at a speed of approximately one Gigabit per second.

18. An optical receiver assembly, comprising

a housing;

mounted inside said housing an optical fiber amplifier that provides a source of light, a lens focusing arrangement, an optical detector and a filter that allows a predetermined range of optical wavelengths to pass through to the optical detector.

19. The assembly of claim 18 wherein the optical detector includes a PIN photodiode that operates at a speed of approximately one Gigabit per second.

20. The assembly of claim 18 wherein a portion of the housing includes an index matching fluid.

21. A method of manufacturing an optical spectrum analyzer, the steps of the method comprising:

providing a housing able to receive a beam of light;

disposing a focusing arrangement within said housing that directs the beam of light;

coupling the beam of light from said focusing arrangement onto a transducer; and

providing an optical filter for blocking a portion of the beam of light while allowing a predetermined range of optical wavelengths to pass through to the transducer.

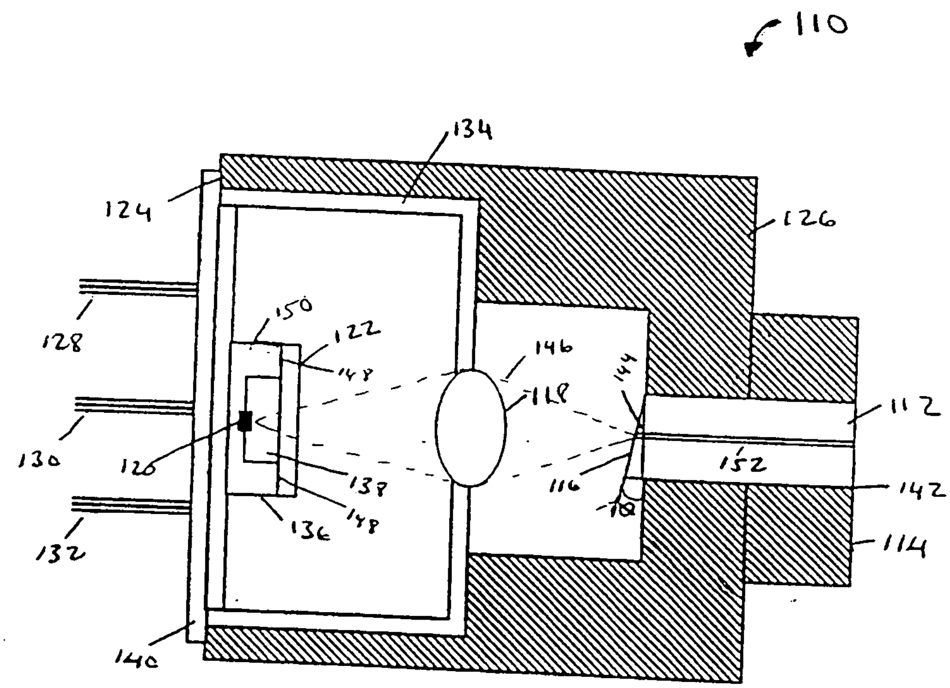
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FIG. 1

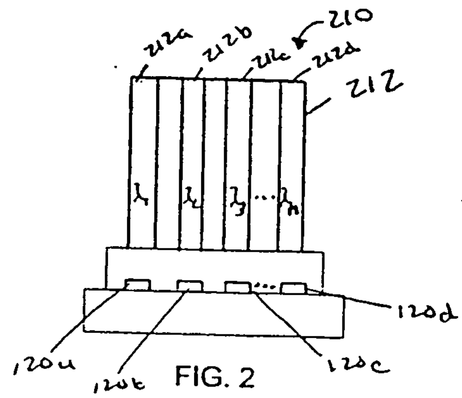
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FIG. 2

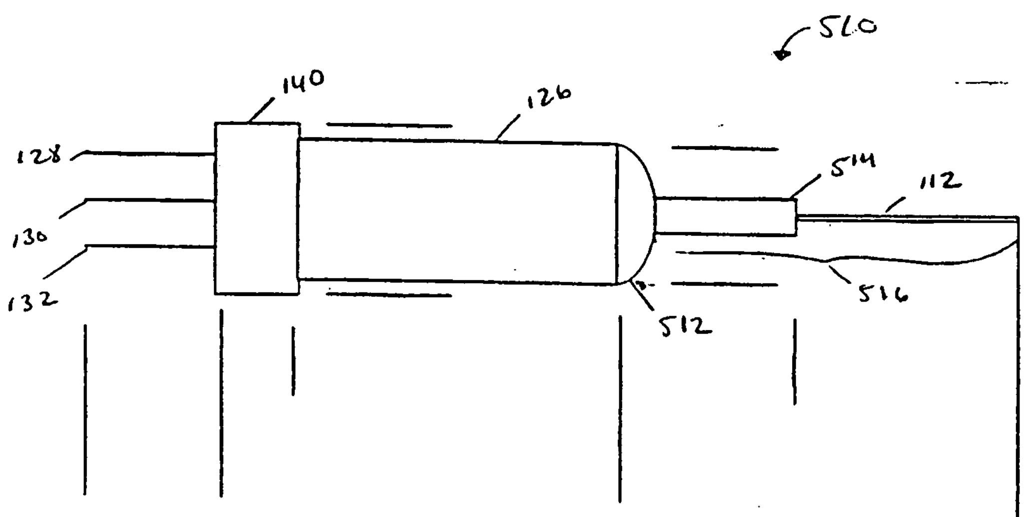
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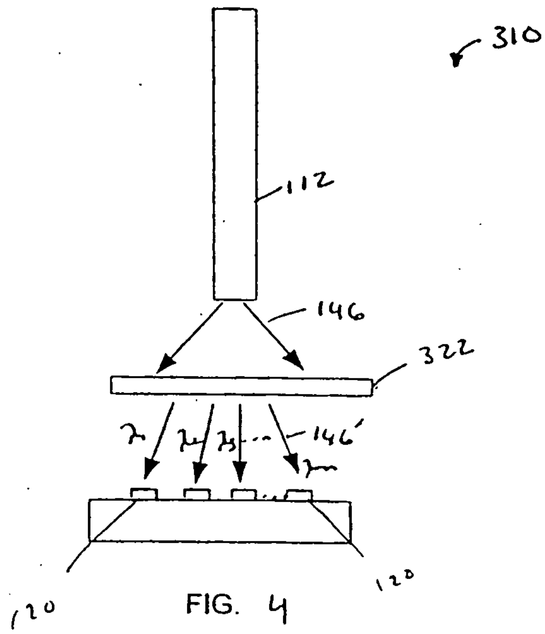
FIG. 3


310
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146
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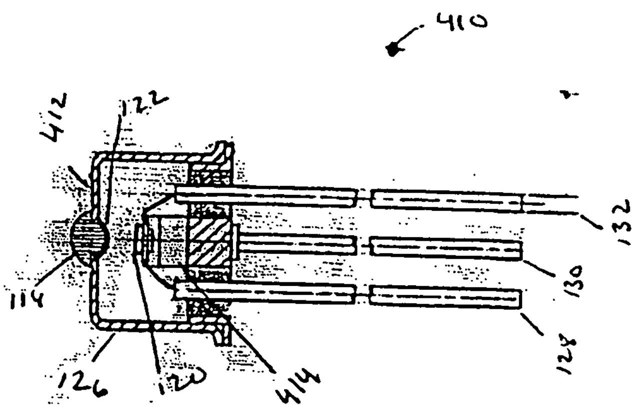
146'
120
120

FIG. 4


410
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122
132
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114
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120
414

FIG. 5

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/40791

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02B6/42 G02B6/293

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 646 399 A (FUKUSHIMA NOBUHIRO ET AL) 8 July 1997 (1997-07-08) abstract; figures 1,3,5,9,12,13 column 1, line 64 -column 2, line 20 column 3, line 34 - line 43	1,10-14, 16,18,21
X	EP 0 901 170 A (SUMITOMO ELECTRIC INDUSTRIES) 10 March 1999 (1999-03-10) abstract; figures 6,16,20 column 17, line 40 -column 19, line 10	1-4,14, 16,18,21
X	US 4 767 171 A (KEIL RUDOLF ET AL) 30 August 1988 (1988-08-30) abstract; figures 1,4-6 column 1, line 36 -column 2, line 62	1,14,16, 18,21

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
31 January 2001	08/02/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Jakober, F

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/40791

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 566 265 A (ALTHAUS HANS-LUDWIG ET AL) 15 October 1996 (1996-10-15) abstract; figures 1,2 column 3, line 15 -column 4, line 6 ---	1-21
A	US 5 291 571 A (UNO SABURO ET AL) 1 March 1994 (1994-03-01) abstract; figures 1,10 -----	1-21

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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